High Performance Gear Obtained by Die Warm Compaction and Rapid Cooling Process

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Abstract

PM recent developments focus on increasing this technology's competitiveness when compared to wrought materials. Warm compaction allows the replacement of a double press double sinter process with a single warm press and sintering step, thus allowing cost and time savings. Moreover there are added benefits to consider such as reducing work in process and lessening part's logistics cost.

This paper presents a successful industrial trial to replace a double press-double sinter process with a warm die compaction and sintering process. The part chosen was a high performance gear containing 0,9% wt. carbon. Sintering was conducted in a belt furnace at 1120ºC in a nitrogen rich atmosphere with rapid cooling process in order to obtain a quasi fully martensitic structure with a minimum of 700HV0,1 and 450HV10 after annealing.

The balance between properties and cost is favoured by the use of a singular lubricant developed in a Eureka frame project together with POMETON S.A. and die warm compaction. Warm compaction is only needed to be effective on the gear teeth, in order to achieve the required properties. Therefore only the die is actually heated. This simplified system avoids flow rate problems typically involved when using more elaborate warm compaction equipments.

Keywords : die warm compaction, lubricant, gear, sinterhardening

1. Introduction

Despite warm compaction being a very well established technology there are few industrial cases where it is being applied. The benefits of this technology are clearly showed in the literature (1), but the 0,1-0,2g/cm^3 of density increase is hardly ever the key factor which determines the best option to choose. Flowability and homogeneity are the major issues that have to be considered when producing PM parts. The base of warm compaction technology depends on the characteristics of the special lubricants at whatever the temperature of compaction. This is especially true at temperatures in the range of 60ºC to 150ºC. At these temperatures and under pressure this kind of lubricants behaves as a liquid, which extends through the bulk mass and eases the powder compaction. Hence this 'warm' lubricant has the major role in warm compaction technology. There are other theories (2) which rely on the increase of the plasticity of the iron powder, to explain the gain of density obtained by this technology.

At that point the special lubricant has to fulfil some characteristics: it must have flowability at temperature up to 150ºC, it must not tend to promote powder or lubricant agglomeration by temperature or humidity, and it should ease the part ejection and be nearly fully removed during sintering. Most of the potential lubricants for that purpose are polymers, which need special temperature profiles during sintering to be completely removed for the PM parts.

Using warm die compaction instead of warm compaction, allows a reduction of the demands made on the lubricant. It is not necessary to show good flowability at die temperature, it is enough to be free flowing at the filling shoe temperature, which is half of the die temperature at most.

The sinterhardening process gives a unique combination of good mechanical characteristics (concerning hardness and elastic behaviour) with moderate cost (no post-heat treatment is required). This is an ideal PM technology for gear production when toughness is not the key factor. High density and hardness is then achieved following a simple route of pressing (warm die compaction) and sintering (sinterhardening) with a reasonable cost.

2. Experimental results and discussion

Figure 1 shows the sinterhardened warm die compacted gear. They were made of Fe-2%Ni-1,5%Mo-0,9%C and the process schedule contained a physical binder mix, warm die compaction at 120ºC at 1000MPa, and sinterhardening at 1120ºC in nitrogen rich atmosphere.

Fig. 1. Industrial gear

Figure 2 shows how the compressibility curve is improved when warm die compaction is employed.

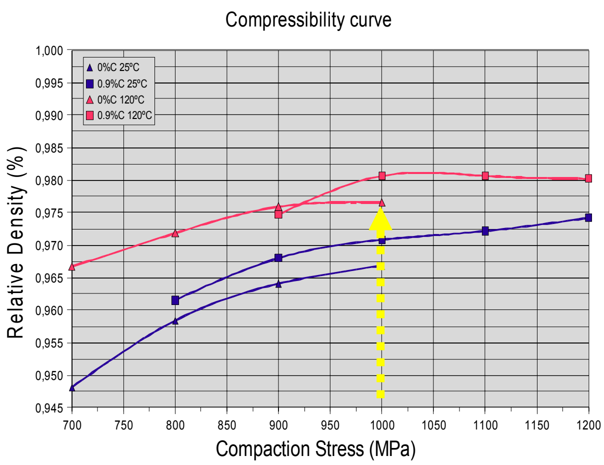

Fig. 2. Compressibility curve in terms of relative density

A 0.98% of relative density is achieved when using die warm compaction; using conventional cold compaction this value of relative density is never achieved, even compacting at 1200MPa.

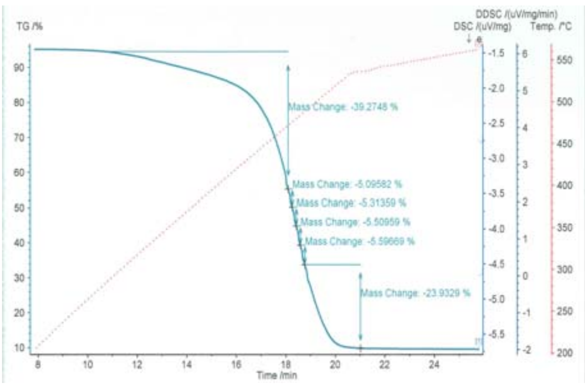

Fig. 3. TGA of the lubricant developed for die warm compaction.

Regarding density values at 700MPa and 1000MPa, we reduce by more than 300MPa the necessary compaction pressure when compacting using warm die compaction technology for the same density level. Hence the die and punches could last longer, helping to reduce maintenance costs.

Final gear density in production series was 7,30g/cm^3 with a bulk hardness of about 700HV0.1. The weight and height scatters were kept to similar values as in case of cold compaction by using a special developed lubricant.

The TGA analysis of the singular lubricant developed for warm die compaction showed a gradual removal when heating from 200ºC to 600ºC (figure 3), which helps the lubricant to exit from the part.

No bubbles or spalling were produced in industrial parts.

The microstructure of the parts reveals a high carbon martensite (figure 4) with some austenitic islands in the bulk mass of it (figure 5). High toughness is not required for these parts.

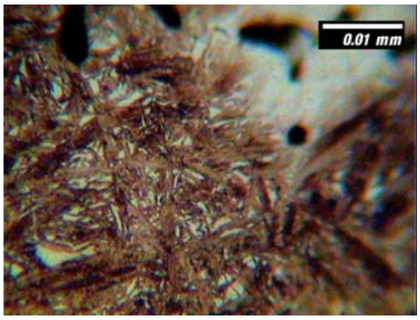

Fig. 4. High carbon martensite

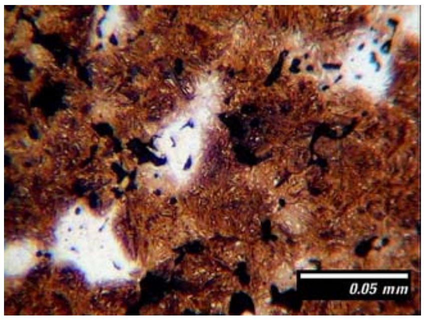

Fig. 5. Ni rich islands in the microstructure

3. Summary

An industrial case of die warm compaction gear combining with sinterharding and using a singular lubricant has been presented. Cost savings comes from the correct combination of different technologies which allows PM to compete and to be a leader in the production of this type of gear.

4. References

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